

Power Engineering (315371)

Model Question Paper — Set B · Model Answers

Q.1

a) COP of a refrigerator.

2 M

COP is the ratio of the refrigerating effect (heat extracted from the cold space) to the work (energy) supplied: $\text{COP} = Q_R/W = RE/W$.

Why COP and not efficiency: efficiency is output/input of the *same* kind of energy and is always less than 1. In a refrigerator the heat removed is usually much larger than the work input, so the ratio is greater than 1; hence the term 'coefficient of performance' is used.

(Definition 1 M, reason 1 M)

b) DPT and RH.

2 M

Dew point temperature (DPT): The temperature to which moist air must be cooled at constant pressure (constant ω) for condensation of water vapour to begin; it is the saturation temperature corresponding to the partial pressure of vapour.

Relative humidity (ϕ): Ratio of the actual vapour pressure in the air to the saturation vapour pressure at the same DBT: $\phi = p_v/p_s$ (usually in %).

(1 M each)

c) IP and indicated thermal efficiency.

2 M

Indicated power (IP): The power developed by the gases inside the engine cylinder, found from the indicator diagram: $\text{IP} = p_m L A n_k / 60 \text{ kW}$.

Indicated thermal efficiency: Ratio of indicated power to the rate of heat supplied by the fuel: $\eta_{\text{ith}} = \text{IP} / (\dot{m}_f \times \text{CV})$.

(1 M each)

d) Isothermal efficiency and capacity.

2 M

Isothermal efficiency: Ratio of isothermal work (power) to the actual indicated work (power) of the compressor: $\eta_{\text{iso}} = p_1 V_1 \ln(p_2/p_1) / \text{IP}$.

Capacity: The volume of air actually delivered by the compressor per minute, measured at free (intake / atmospheric) conditions — i.e. free air delivery, m^3/min .

(1 M each)

e) Effects of exhaust emissions.

2 M

1. **CO** combines with haemoglobin of blood and reduces oxygen supply — headache, dizziness, even death in closed spaces.
2. **HC and NO_x** react in sunlight to form photochemical smog and ground-level ozone — eye irritation and breathing problems.

3. **NO_x and SO_x** form acid rain, damaging crops, buildings and water bodies.
4. **Particulate matter (soot)** causes lung diseases and reduces visibility; CO₂ adds to global warming.

(Any four, ½ M each)

f) Components of aqua-ammonia VAR system.

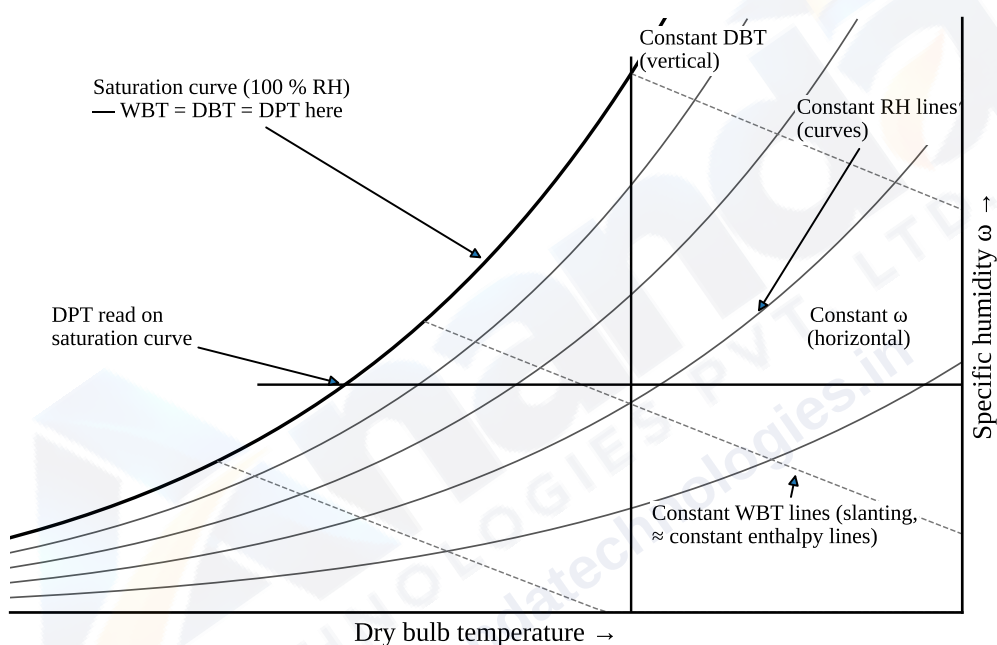
2 M

1. Generator (with heat source)
2. Condenser
3. Expansion valve
4. Evaporator
5. Absorber (with cooling water)
6. Liquid pump; heat exchanger and pressure-reducing valve for the weak solution

(Any four, ½ M each)

g) Psychrometric chart lines.

2 M



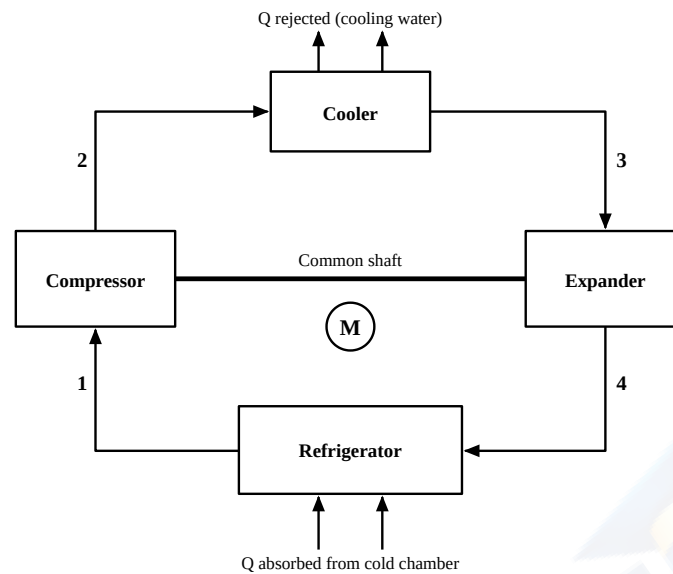
Skeleton psychrometric chart showing the main lines

(Sketch 1 M, lines 1 M)

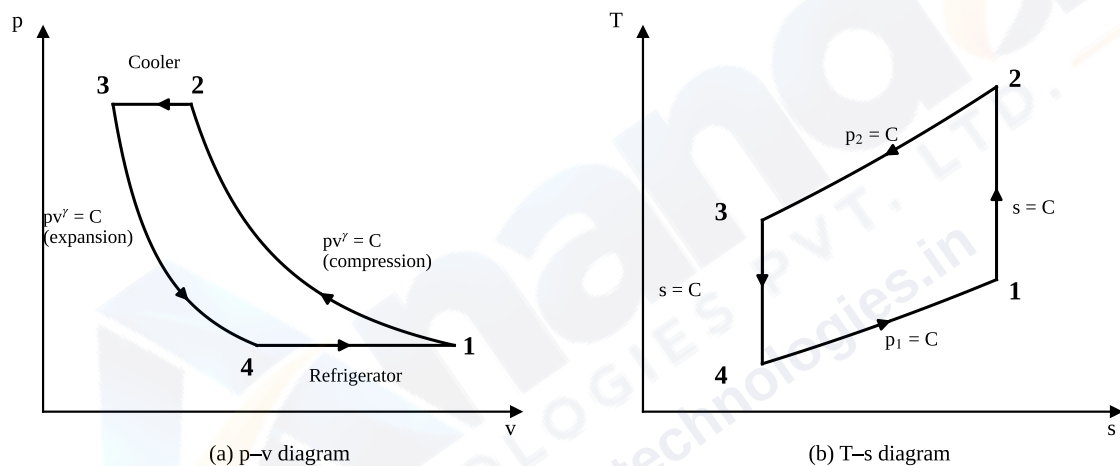
Q.2

a) Bell-Coleman cycle and COP.

4 M



Bell-Coleman (closed / dense-air) refrigeration system



Bell-Coleman (reversed Brayton) air refrigeration cycle

- **1–2 Isentropic compression:** air from the refrigerator is compressed from p_1 to p_2 ; temperature rises from T_1 to T_2 .
- **2–3 Constant-pressure cooling:** hot air is cooled in the cooler (heat exchanger) at p_2 by cooling water, $T_2 \rightarrow T_3$.
- **3–4 Isentropic expansion:** air expands in the expander from p_2 to p_1 ; temperature falls to T_4 (much below the cold-chamber temperature). Expander work helps drive the compressor.
- **4–1 Constant-pressure heat absorption:** cold air absorbs heat from the refrigerator (cold chamber) at p_1 , $T_4 \rightarrow T_1$. This is the refrigerating effect.

COP: Heat absorbed $q_a = c_p(T_1 - T_4)$; heat rejected $q_r = c_p(T_2 - T_3)$; work = $q_r - q_a$.

$$\text{COP} = (T_1 - T_4) / [(T_2 - T_3) - (T_1 - T_4)] = 1 / [(p_2/p_1)^{(\gamma-1)/\gamma} - 1]$$

(Since $T_2/T_1 = T_3/T_4 = (p_2/p_1)^{(\gamma-1)/\gamma}$ for the two isentropic processes.) Used in aircraft refrigeration because air is light, safe and freely available, though COP is low.

(Schematic 1 M, $p-v$ and $T-s$ 1 M, processes 1 M, COP 1 M)

b) Selection of air compressor.

4 M

Application	Suitable compressor	Justification
Spray painting in a small garage	Single-stage (or two-stage) reciprocating, air-cooled, with receiver	Small flow at 6–8 bar; cheap, portable, easy start–stop control; receiver smooths pulsations.
Blast-furnace air supply	Centrifugal (or axial) blower / compressor	Very large volume at low pressure ratio; continuous, oil-free, smooth delivery; high efficiency at design point.
Aircraft gas turbine engine	Multistage axial flow compressor	Very high mass flow with small frontal area and light weight; high efficiency; pressure ratio built up by many stages.
Turbocharging an automobile engine	Centrifugal compressor (driven by exhaust gas turbine)	Compact, very high speed, light; gives large flow at moderate pressure ratio (1.5–2.5); couples directly to turbine shaft.

(Each correct choice with reason 1 M)

c) Factors affecting comfort air conditioning.

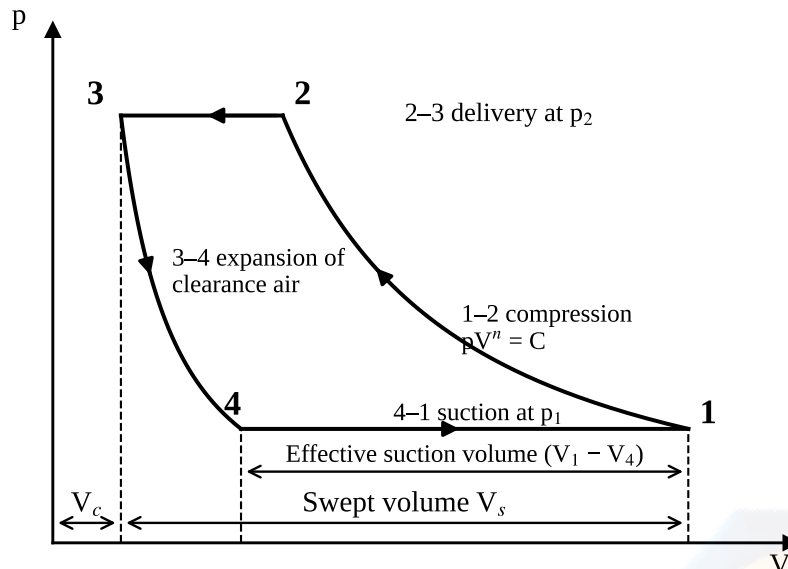
4 M

- **Temperature:** Comfortable dry-bulb temperature is about 22–26 °C in summer and 19–22 °C in winter; the body loses heat easily only within this range.
- **Humidity:** Relative humidity of 40–60 % is comfortable; high humidity prevents evaporation of sweat, low humidity dries the skin and throat.
- **Air motion (velocity):** Air velocity of about 6–9 m/min (0.1–0.15 m/s) in the occupied zone removes heat and moisture from the body without causing draught.
- **Purity of air:** Air must be free from dust, odour, bacteria and CO₂ — fresh air ventilation and filters are provided.

(Any four, 1 M each)

d) Need of clearance volume.

4 M



Indicator (p - V) diagram of a single-stage reciprocating compressor with clearance

Justification (why clearance is provided):

- To avoid the piston striking the cylinder head and valves at the end of the stroke (thermal expansion of piston and rod, wear of bearings).
- To give space for the suction and delivery valves and their movement.
- To allow for manufacturing tolerances and a cushion of air at the end of delivery.

Is a large clearance desirable? — No. The high-pressure air left in the clearance (point 3) expands along 3-4 before fresh air can enter. Larger clearance $\Rightarrow$ larger 3-4 expansion $\Rightarrow$ smaller effective suction volume ($V_1 - V_4$).

$$\eta_{vol} = 1 - C [(p_2/p_1)^{1/n} - 1]$$

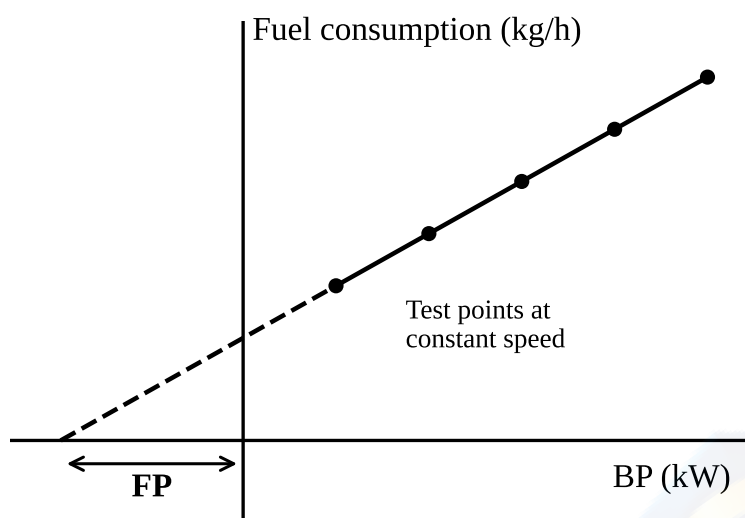
So volumetric efficiency and capacity fall (a bigger, costlier cylinder is needed). Clearance is therefore kept small, about 4–10 % of swept volume.

(Justification 2 M, effect with diagram 2 M)

Q.3

a) Willan's line method.

4 M



Willan's line: fuel consumption vs BP extrapolated to zero fuel gives FP

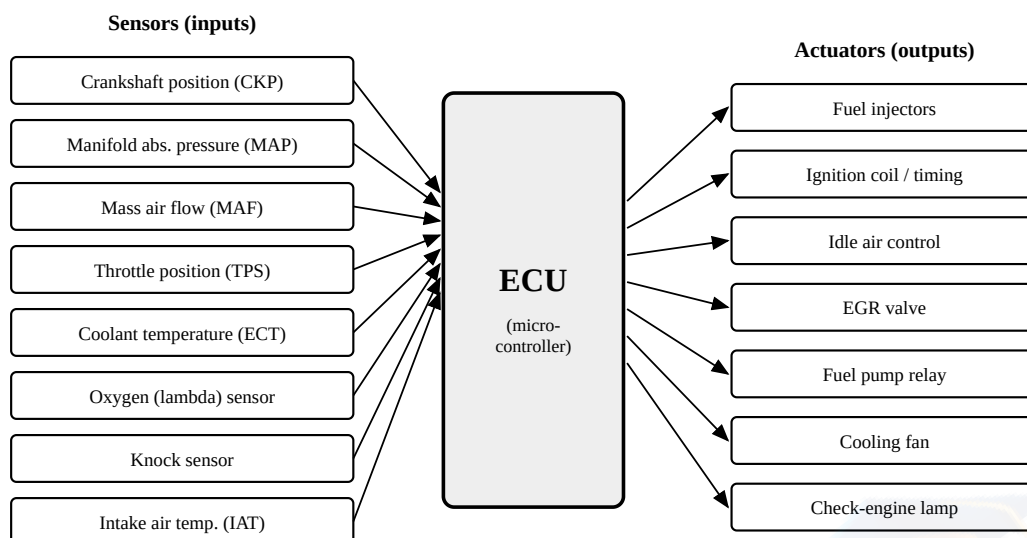
1. The engine (diesel) is run at constant speed and the load is varied from no load to full load in steps.
2. At each load the BP and the fuel consumption (kg/h) are measured.
3. A graph of fuel consumption against BP is plotted. It is nearly a straight line (Willan's line) at constant speed.
4. The line is extended backwards until it cuts the BP axis (zero fuel). The negative intercept on the BP axis gives the **friction power**. Then $IP = BP + FP$ and $\eta_m = BP/IP$.

Limitation: valid only for CI engines (fuel-load relation is linear only for quality-governed engines) and only at constant speed; extrapolation near zero load is uncertain, so the result is approximate.

(Graph 1 M, procedure 2 M, limitation 1 M)

b) Sensors used in ECU.

4 M



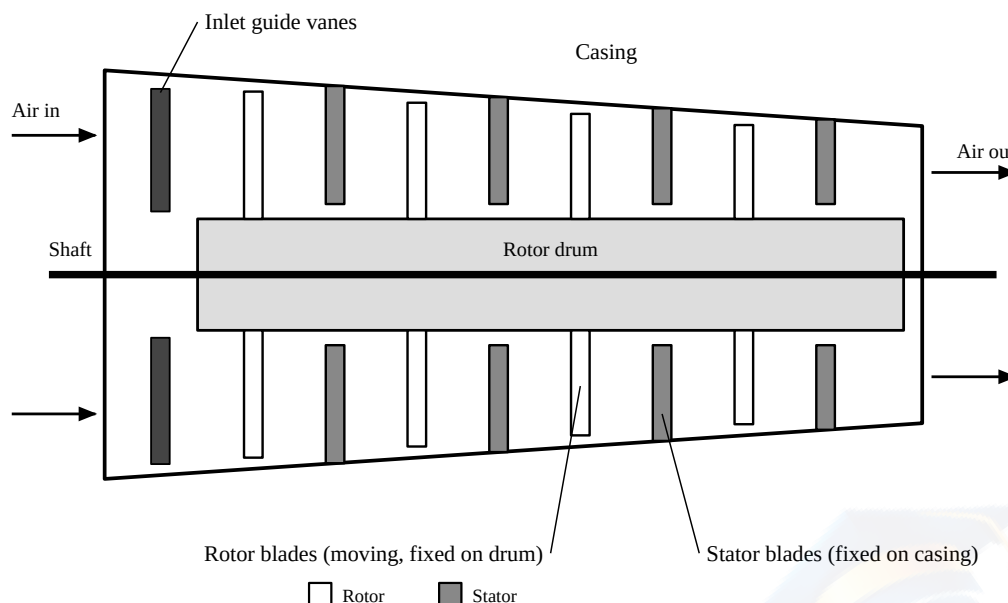
Engine control unit (ECU) with input sensors and output actuators

Sensor	Function
Crankshaft position (CKP) sensor	Gives engine speed and piston position; used for ignition timing and injection timing.
Manifold absolute pressure (MAP) / mass air flow (MAF) sensor	Measures engine load / air entering the engine; ECU calculates fuel quantity.
Throttle position sensor (TPS)	Tells the throttle opening and rate of opening (driver demand) for acceleration enrichment.
Engine coolant temperature (ECT) sensor	Tells engine temperature; richer mixture and faster idle during cold start; controls cooling fan.
Oxygen (lambda) sensor	Measures O ₂ in exhaust; ECU keeps air–fuel ratio near stoichiometric (closed-loop control) for the catalytic converter.
Knock sensor	Detects detonation (vibration); ECU retards ignition timing.

(Any four sensors with function, 1 M each)

c) Axial flow compressor.

4 M



Axial flow compressor (sectional view)

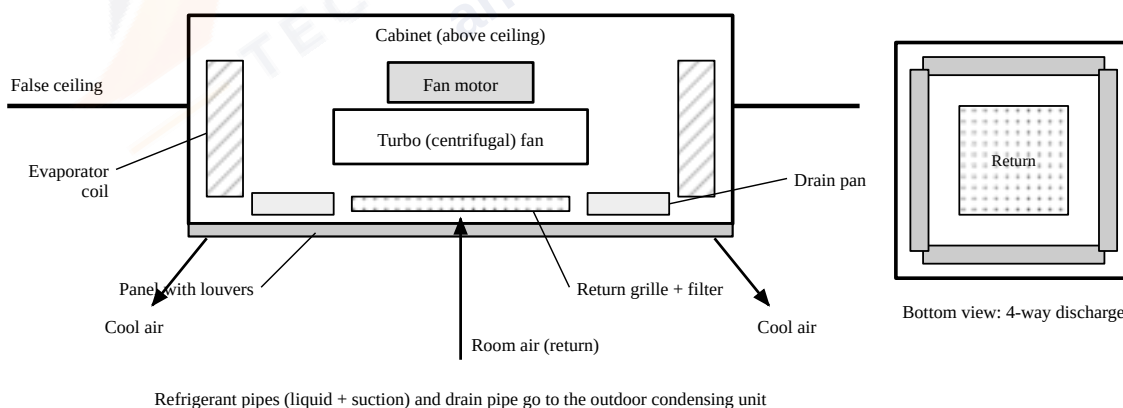
Construction: It has a rotor (drum) carrying several rows of aerofoil-section **moving blades** and a casing carrying rows of **fixed (stator) blades** placed alternately between them. One row of moving blades and the following row of fixed blades form one **stage**. Inlet guide vanes direct air at the correct angle into the first stage. The annulus area reduces from inlet to outlet because air density increases.

Working: Air flows parallel to the axis. The rotating blades do work on the air and increase its kinetic energy and pressure; the fixed blades act as diffusers, converting kinetic energy into pressure and guiding the air to the next row at the correct angle. Each stage gives a small pressure rise (ratio about 1.1–1.3); many stages give a high overall pressure ratio. Used in gas turbines and jet engines.

(Sketch 2 M, construction 1 M, working 1 M)

d) 4-way ceiling-mounted cassette AC.

4 M



Ceiling-mounted 4-way cassette air conditioner (indoor unit section and bottom view)

Construction: The indoor unit is fitted in the false ceiling; only the decoration panel is visible. It contains a turbo (centrifugal) fan at the centre driven by a motor, an evaporator coil arranged round

the fan, a drain pan with a drain pump, an air filter behind the central return grille and four motorised louvers. It is connected by refrigerant pipes to an outdoor condensing unit (compressor, condenser and fan).

Working: Room air is sucked upward through the central grille and filter by the turbo fan and thrown radially through the cold evaporator coil, where it is cooled and dehumidified. The cool air is discharged through the 2 or 4 side slots; the swinging louvers spread it evenly in all directions. Condensate collects in the drain pan and is pumped out. The refrigerant cycle is completed in the outdoor unit.

(Sketch 2 M, working 2 M)

Q.4

a) Reciprocating vs rotary compressor.

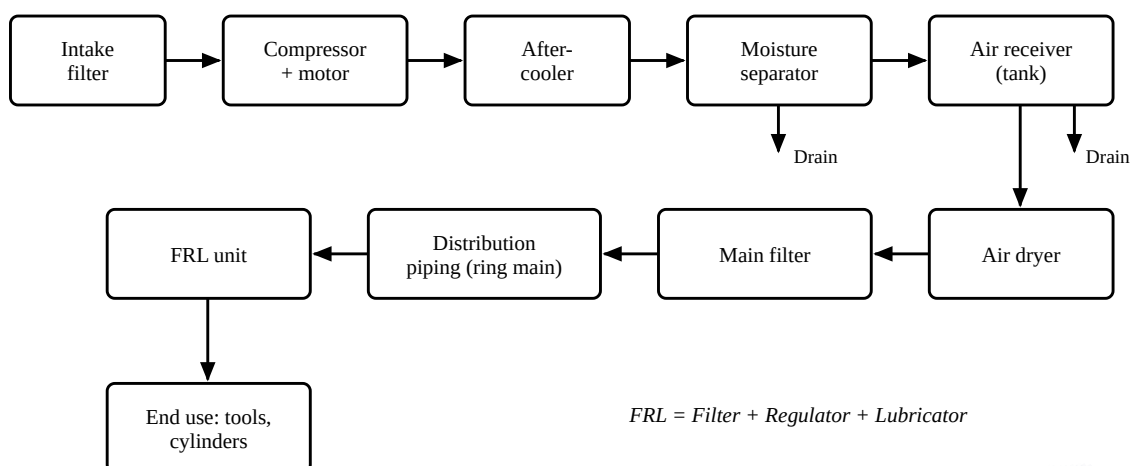
4 M

Parameter	Reciprocating compressor	Rotary compressor (screw / vane / lobe)
Construction	Piston, cylinder, crank, connecting rod, valves; heavy foundation needed.	Rotors / vanes in a casing; no valves; compact and light.
Efficiency	Higher isothermal efficiency at high pressure ratio (multistage + intercooling).	Lower at high pressure ratio; good at moderate pressure.
Noise level	Noisy; vibrations due to unbalanced reciprocating parts.	Quieter; smooth, balanced rotation.
Air flow	Pulsating flow; receiver required.	Continuous, nearly steady flow.
Pressure level	High pressures (up to 100 bar or more with stages).	Low to moderate pressures (up to about 10–13 bar for screw).
Application	Small and medium quantities at high pressure — workshops, garages, gas filling.	Large quantities at moderate pressure — industries, plant air, superchargers.
Maintenance	More wear (rings, valves); higher maintenance.	Less wear; lower maintenance.
Connection with prime mover	Low speed; usually belt-driven or through gear from motor / engine.	High speed; directly coupled to electric motor / turbine.

(Any eight points, ½ M each)

b) Main components of compressed air system.

4 M



Main components of a compressed air system

Component	Role
Intake air filter	Removes dust from intake air; protects compressor from wear.
Compressor with motor	Raises air pressure to the required value.
After-cooler	Cools the hot compressed air; condenses most of the moisture.
Moisture separator / drain traps	Removes condensed water and oil droplets.
Air receiver	Stores air, damps pulsations, meets peak demand, allows further moisture to settle; reduces compressor starts.
Air dryer (refrigerated / desiccant)	Lowers dew point so that no water condenses in pipes and tools.
Distribution piping (ring main)	Carries air to user points with minimum pressure drop.
FRL unit	Filter, regulator (sets pressure) and lubricator at each machine.

(Layout 2 M, roles 2 M)

c) Energy-saving checklist for 100 L water cooler.

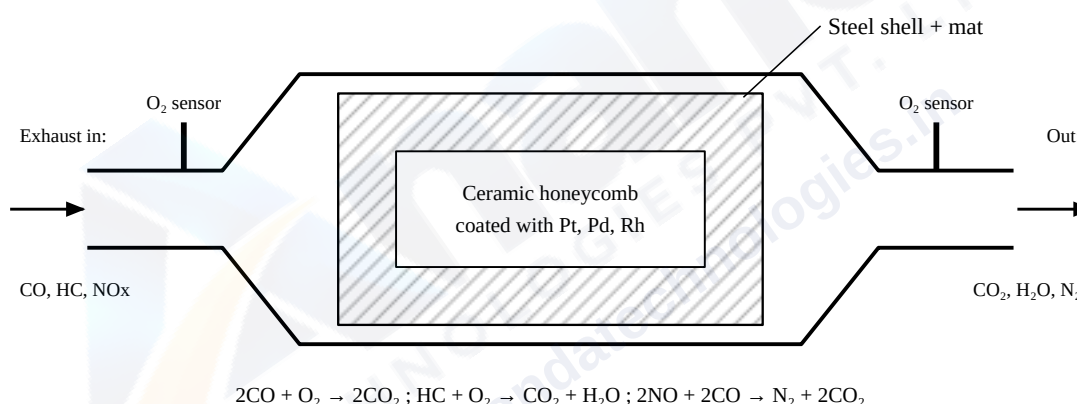
4 M

No.	Check point	Yes / No
1	Cooler installed in a shaded, well-ventilated place, at least 15–20 cm away from the wall; not in direct sunlight or near heat sources.	☐
2	Condenser coil and fan cleaned regularly (dust-free); fan running properly.	☐
3	Thermostat set at about 12–15 °C (not lower than needed).	☐
4	Tank insulation intact; tank lid and float valve not leaking (no overflow of cooled water).	☐
5	Taps not leaking; cooled water not wasted; timer switches off the cooler after working hours / holidays.	☐
6	Refrigerant charge, capillary / filter-drier and compressor current checked during maintenance.	☐
7	Inlet water pre-filtered and not hot (supply pipe not exposed to sun).	☐
8	Star-rated / energy-efficient model chosen and capacity matched to number of users.	☐

(Any eight points, ½ M each)

d) Three-way catalytic converter.

4 M



Three-way catalytic converter

Construction: A stainless-steel shell in the exhaust line contains a ceramic (cordierite) or metallic honeycomb monolith coated with a wash-coat of alumina and precious metals — **platinum and palladium** (oxidation catalysts) and **rhodium** (reduction catalyst). Oxygen sensors are fitted before and after it.

Working: It is called 'three-way' because it controls CO, HC and NO_x simultaneously: CO and HC are **oxidised** to CO₂ and H₂O, while NO_x is **reduced** to N₂. It works effectively only when the air–fuel ratio is kept close to stoichiometric (≈ 14.7:1) by the ECU using the lambda sensor, and above its light-off temperature (about 250–300 °C). Leaded fuel poisons the catalyst.

(Sketch 2 M, working with reactions 2 M)

e) Two-stage compressor numerical.

4 M

Given: $\dot{m} = 4 \text{ kg/min} = 0.06667 \text{ kg/s}$, $p_1 = 1 \text{ bar}$, $T_1 = 20^\circ\text{C} = 293.15 \text{ K}$, $p_3 = 12 \text{ bar}$, $n = 1.25$, $R = 0.287 \text{ kJ/kg}\cdot\text{K}$

Intermediate pressure (perfect intercooling, minimum work): $p_2 = \sqrt{(p_1 p_3)} = \sqrt{(1 \times 12)} = \mathbf{3.464 \text{ bar}}$

$$IP = 2 \cdot [n/(n-1)] \cdot \dot{m} R T_1 \cdot [(p_3/p_1)^{(n-1)/2n} - 1]$$

$$(n-1)/2n = 0.1000; (p_3/p_1)^{(n-1)/2n} = (12)^{0.1000} = 1.2821$$

$$IP = 2 \times 5.0000 \times 0.06667 \times 0.287 \times 293.15 \times (1.2821 - 1) = \mathbf{15.82 \text{ kW}}$$

$$\text{Isothermal power} = \dot{m} R T_1 \ln(p_3/p_1)$$

$$= 0.06667 \times 0.287 \times 293.15 \times \ln(12) = 0.06667 \times 0.287 \times 293.15 \times 2.4849 = \mathbf{13.94 \text{ kW}}$$

$$\text{Isothermal efficiency} = 13.94/15.82 = \mathbf{88.1 \%}$$

Note: single-stage compression to the same pressure would need 18.05 kW, so two-stage compression with intercooling saves 2.23 kW (12.4 %). Delivery temperature of each stage = $293.15 \times (3.464)^{0.2000} = 375.8 \text{ K}$ (102.7 °C).

(p₂ 1 M, IP 1½ M, isothermal power 1 M, efficiency ½ M)

Q.5

a) Reversed Carnot refrigerator — ice production.

6 M

Given: Capacity = 15 TR = $15 \times 3.5 = 52.5 \text{ kW}$; $T_2 = -8 + 273.15 = 265.15 \text{ K}$; $T_1 = 30 + 273.15 = 303.15 \text{ K}$

$$\text{(i) COP (reversed Carnot)} = T_2/(T_1 - T_2) = 265.15/(303.15 - 265.15) = \mathbf{6.978}$$

Heat to be removed from 1 kg of water at 20 °C to make ice at 0 °C:

$$q = c_w(t_w - 0) + L = 4.187 \times 20 + 335 = 83.74 + 335 = 418.74 \text{ kJ/kg}$$

$$\text{Heat extracted per day} = 52.5 \text{ kJ/s} \times 86400 \text{ s} = 4,536,000 \text{ kJ/day}$$

$$\text{(ii) Ice produced} = 4,536,000/418.74 = \mathbf{10,832 \text{ kg/day} \approx 10.83 \text{ tonnes/day}}$$

$$\text{(iii) Power} = \text{Refrigerating capacity} / \text{COP} = 52.5/6.978 = \mathbf{7.52 \text{ kW}}$$

(COP 2 M, ice per day 2 M, power 2 M)

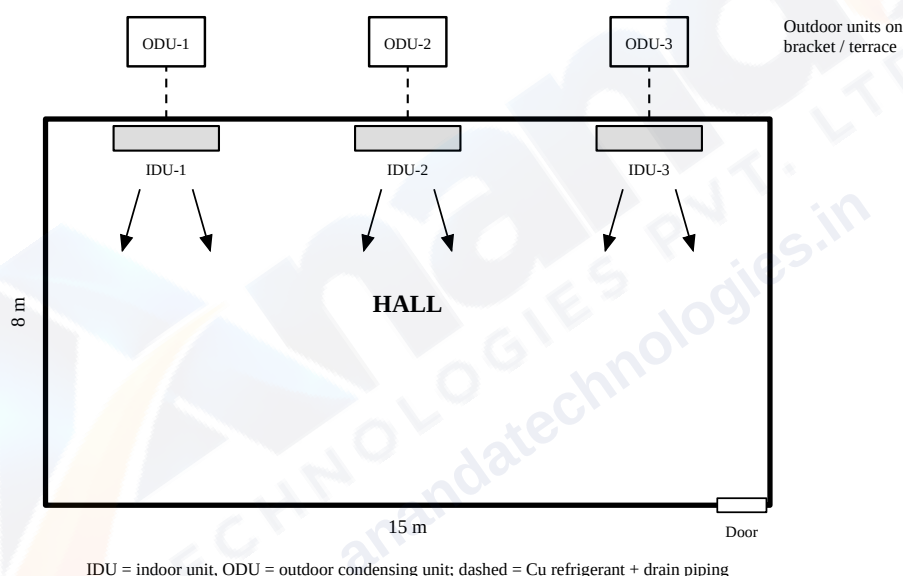
b) Air-conditioning system for a seminar hall.

6 M

Rough cooling-load estimate (assumed design: outside 38 °C DBT, 40 % RH; inside 24 °C DBT, 50 % RH; floor area 120 m², volume 420 m³):

Load item	kW
Occupants – sensible ($60 \times 75 \text{ W}$)	4.50
Occupants – latent ($60 \times 55 \text{ W}$)	3.30
Lights ($120 \text{ m}^2 \times 12 \text{ W/m}^2$)	1.44
Projector, PCs, sound system (assumed)	1.00
Walls, roof and glass (assumed 50 W/m^2 of floor $\times 120 \text{ m}^2$)	6.00
Fresh air: $60 \times 5 \text{ L/s} = 0.30 \text{ m}^3/\text{s}$; $\dot{m} = 0.331 \text{ kg/s} \times (81.2 - 47.8) \text{ kJ/kg}$	11.07
Total	27.31
Add 10 % safety	30.04
Cooling capacity required	$\approx 8.6 \text{ TR}$

Suggested system: 8.6 TR is too large for one domestic unit, and the hall needs even air distribution. Hence **three ceiling-mounted cassette (or ductable split) units of 3 TR each (total 9 TR)** are suggested, spaced along the length of the hall, with their outdoor condensing units on a wall bracket / terrace. (For a single small room such as a classroom, one or two hi-wall split units are enough.) Inverter units with BEE star rating save energy at part load.



Layout: seminar hall 15 m x 8 m with three indoor cassette units (IDU) and outdoor units (ODU)

Working: Each indoor unit draws hall air through its filter and over the cold evaporator, where the air is cooled and dehumidified, and throws it out through 4-way louvers. The refrigerant vapour is compressed in the outdoor unit, condensed in the air-cooled condenser, throttled in the expansion device and returned to the evaporator. Fresh air is admitted through a small fresh-air duct / exhaust fan to keep CO_2 low; thermostats keep the hall at about 24°C and 50 % RH. Condensate is drained outside.

(Load / selection 2 M, layout 2 M, working 2 M)

c) Motoring test and heat balance sheet.

6 M

(i) $\text{BP} = 2\pi\text{NT}/60000 = 2\pi \times 700 \times 150/60000 = 10.996 \text{ kW}$

(ii) Motoring test: power needed to drive the engine at the same speed = friction power, $FP = 2.2$ kW

$$IP = BP + FP = 10.996 + 2.2 = \mathbf{13.196 \text{ kW}}; \eta_m = BP/IP = 10.996/13.196 = \mathbf{83.33 \%}$$

(iii) Heat balance per minute:

- Heat supplied = $(3.1/60) \times 41,000 = \mathbf{2118.33 \text{ kJ/min}}$
- Heat equivalent of BP = $10.996 \times 60 = \mathbf{659.73 \text{ kJ/min}}$
- Cooling water = $(700/60) \times 4.187 \times 12 = \mathbf{586.18 \text{ kJ/min}}$
- Air used = $A/F \times m_f = 30 \times 3.1 = 93 \text{ kg/h}$; exhaust gas = $(93 + 3.1)/60 = 1.6017 \text{ kg/min}$
- Heat to exhaust = $1.6017 \times 1.05 \times (360 - 28) = \mathbf{558.34 \text{ kJ/min}}$
- Unaccounted = $2118.33 - (659.73 + 586.18 + 558.34) = \mathbf{314.08 \text{ kJ/min}}$

Heat supplied (kJ/min)			Heat distributed (kJ/min)		
Item	kJ/min	%	Item	kJ/min	%
Heat supplied by fuel ($m_f \times CV$)	2118.33	100.00	Heat equivalent of BP	659.73	31.14
			Heat carried by cooling water	586.18	27.67
			Heat carried by exhaust gases	558.34	26.36
			Heat unaccounted (by difference)	314.08	14.83
Total	2118.33	100.00	Total	2118.33	100.00

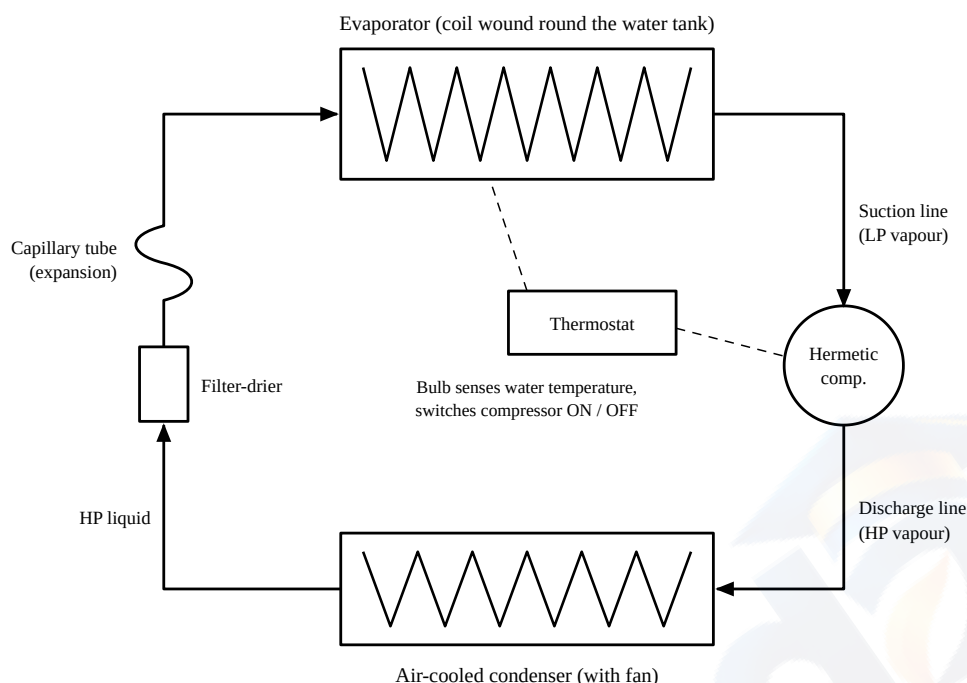
Brake thermal efficiency = $659.73/2118.33 = 31.14 \%$; indicated thermal efficiency = $791.73/2118.33 = 37.38 \%$.

(BP 1 M, IP and η_m 1 M, heat balance sheet 4 M)

Q.6

a) Refrigeration system of a 100 L water cooler.

6 M



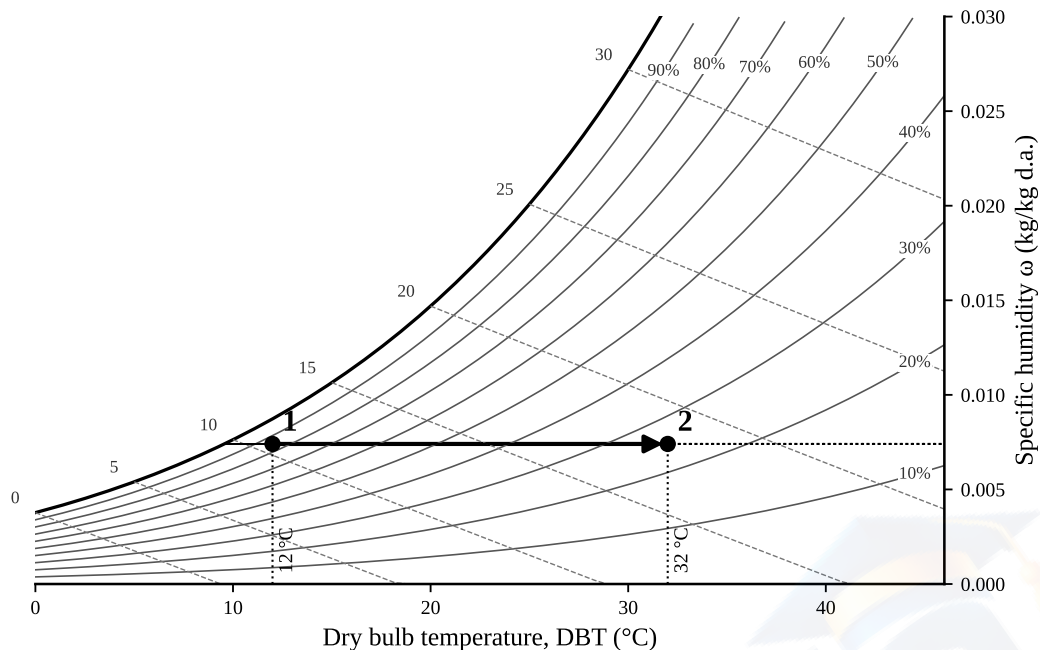
Refrigeration circuit of a storage-type water cooler

- **Compressor (hermetic):** sucks low-pressure vapour from the evaporator and compresses it to high pressure and temperature.
- **Condenser (air-cooled, fan-forced):** the hot vapour gives its heat to the atmospheric air and condenses into high-pressure liquid.
- **Filter-drier:** removes moisture and dirt so that the capillary does not choke.
- **Capillary tube:** throttles the liquid to the evaporator pressure; temperature falls to about 0–5 °C.
- **Evaporator coil** (copper tube wound round the stainless-steel tank): the refrigerant evaporates by taking heat from the water through the tank wall; the water is cooled to the set temperature.
- **Thermostat:** its bulb senses water temperature and switches the compressor ON / OFF (about 10–15 °C).
- The vapour returns to the compressor and the cycle repeats (simple vapour compression cycle, refrigerant R-134a / R-290).

(Sketch 3 M, working 3 M)

b) Sensible heating numerical.

6 M



Sensible heating 1 → 2: horizontal line (ω constant), DBT increases

State 1 (12 °C, 85 % RH):

- Saturation pressure at 12 °C (steam table): $p_s = 1.4026$ kPa
- Vapour pressure $p_v = \phi p_s = 0.850 \times 1.4026 = 1.1922$ kPa
- Specific humidity $\omega = 0.622 p_v / (p - p_v) = 0.622 \times 1.1922 / (101.325 - 1.1922) = \mathbf{0.00741 \text{ kg/kg d.a.}}$
- Dew point temperature = saturation temperature at $p_v = \mathbf{9.6^\circ\text{C}}$
- Enthalpy $h = 1.005 t + \omega(2500 + 1.88 t) = 1.005 \times 12 + 0.00741(2500 + 1.88 \times 12) = \mathbf{30.74 \text{ kJ/kg d.a.}}$
- Specific volume $v = R_a T / (p - p_v) = 0.287 \times 285.15 / (101.325 - 1.1922) = \mathbf{0.8173 \text{ m}^3/\text{kg d.a.}}$
- Wet bulb temperature (from chart, along constant-WBT line through the state) = $\mathbf{10.6^\circ\text{C}}$

Sensible heating: no moisture is added, so $\omega_2 = \omega_1 = 0.00741$ kg/kg and $p_{v2} = p_{v1} = 1.1922$ kPa.

p_s at 32 °C = 4.7585 kPa $\Rightarrow$ (i) $\phi_2 = p_v / p_s = 1.1922 / 4.7585 = \mathbf{25.1\%}$; WBT₂ (chart) = $\mathbf{18.2^\circ\text{C}}$

(ii) Dew point stays the same: DPT = $\mathbf{9.6^\circ\text{C}}$ (ω constant)

$h_2 = 1.005 \times 32 + 0.00741(2500 + 1.88 \times 32) = 51.12$ kJ/kg d.a.

Mass of dry air $\dot{m}_a = V / v_1 = 1.2 / 0.8173 = 1.4683$ kg/s

(iii) Heat added = $\dot{m}_a(h_2 - h_1) = 1.4683 \times (51.12 - 30.74) = \mathbf{29.92 \text{ kW}}$

Values are calculated from psychrometric relations at $p = 1.01325$ bar (saturation pressures from steam tables); readings taken from the chart will agree within about $\pm 0.5^\circ\text{C}$ and ± 1 kJ/kg.

(Chart sketch 1 M, RH & WBT 2 M, DPT 1 M, heat 2 M)

c) Morse test (torque data).

6 M

(i) BP with one cylinder cut = $2\pi NT / 60000 = 2\pi \times 1500 \times 130 / 60000 = \mathbf{20.420 \text{ kW}}$

IP of one cylinder = BP - BP_{cut} = $30 - 20.420 = 9.580$ kW

(ii) All four cylinders are identical: $IP = 4 \times 9.580 = 38.32 \text{ kW}$

(iii) $\eta_m = 30/38.32 = 78.29 \%$

Fuel used = $BSFC \times BP = 0.3 \times 30 = 9.00 \text{ kg/h}$; heat supplied = $(9.00/3600) \times 44,000 = 110.00 \text{ kW}$

(iv) $\eta_{ith} = IP/\text{heat supplied} = 38.32/110.00 = 34.84 \%$ ($\eta_{bth} = 27.27 \%$)

($BP_{cut} \text{ 1 M, IP 2 M, } \eta_m \text{ 1 M, } \eta_{ith} \text{ 2 M}$)

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